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THE RELATION OF THE SOUTHERN APPALACHIAN MOUNTAINS TO INLAND WATER NAVIGATION.

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On March 4, 1907, Congress passed the following provision in connection with the Agricultural appropriation bill:

Survey of and report on Appalachian and White Mountain watersheds.—To enable the Secretary of Agriculture to examine, survey, and ascertain the natural conditions of the watersheds at and near the sources of the various rivers having their sources in the Southern Appalachian Mountains and the White Mountains, and to report to Congress the area and natural conditions of said watersheds, the price at which the same can be purchased by the Government, and the advisability of the Government purchasing and setting apart the same as national forest reserves for the purpose of conserving and regulating the water supply and flow of said streams in the interest of agriculture, water power, and navigation * * *.

Because of its identification with studies of stream flow and its facilities for stream measurement arrangement was made with the Geological Survey for a study of the water resources of the Soutnern Appalachian Mountains. The following report on The Relation of the Southern Appalachian Mountains to Inland Water Navigation has resulted from that study.

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THE RELATION OF THE SOUTHERN APPALACHIAN MOUNTAINS TO INLAND WATER NAVIGATION.

INTRODUCTION.

The United States had up to June 30, 1905, expended nearly $30,000,000 to improve navigation in rivers that have their upland sources in the Southern Appalachian Mountains. Including the Ohio River, which is so largely supplied with water from this mountain area, the total expenditure amounted to more than $36,000,000. With this expenditure freight shipments over these rivers amounted in the year 1905 to 14,614,781 tons, together with 196,000,000 feet B. M. of lumber. The projects for improvement authorized by Congress on these rivers are not yet complete. On some of them, indeed, the work has hardly commenced. When finished the cost, excluding improvements on the Ohio proper, will be more than $56,000,000, according to present estimates.

The reason for this relatively small amount of traffic compared with the large expenditure lies in the fact that under present conditions the rivers fail to provide a depth of water throughout the year sufficient for navigation. There are seasons of high water in which deep-draft vessels may pass readily up and down these rivers with open navigation and plenty of water under the keel. This is in the high tide of the year when the rivers are glutted with rain or melted snow shed by prodigal hills and mountains, and when they carry millions of tons of sediment eroded from the cleared mountain slopes. It is a period of short duration, always followed by weeks of privation, when the sediment has been deposited and the rivers are in need of the water that they have so ruthlessly wasted. It is this condition of alternating silt-bearing floods and low water that makes it necessary for the Government to expend millions—first, to provide depth of channel sufficient for navigation, and, second, to remove deposited detritus in order that the depth of channel may be maintained.

The chief obstacles to navigation, then, are lack of water during portions of the year, and detritus which is washed into the streams and which gradually fills the channels or forms obstructions at the mouth. Were the flow uniform, the amount of water carried by a river during the year would be sufficient to provide a good depth at all times. But the flow is uneven; there is too much water at one time and not enough at another. The floods of the spring waste the

water which should be available to maintain a navigable depth during summer and fall. To lessen this inequality of flow should therefore be the aim of all measures for the development of our waterways. If the rivers could be kept always in gentle flood a relatively small expenditure for reservoirs, locks, and dams would be required. In the same way, if means could be found to prevent silt and sand from being washed into the streams the enormous cost of dredging would be largely done away with.

One factor which tends to make the flow of streams uneven is the unevenness of the rainfall. Rain comes at irregular intervals and varies in intensity. In consequence, the amount of water which in different seasons runs off the land into the rivers varies also. Yet there are natural factors through which a part at least of this variability may be overcome. Among the most important of these is the vegetation which covers the slopes upon which the rain falls. In itself, and in the effect which it has upon the soil, it causes the water to be fed gradually into the streams, and so tends to bring about a uniform flow. The amount of surface soil which is washed from bare slopes in the Southern Appalachians is enormous. Not only does growth upon the slopes tend to keep the flow even, but it is also the chief agent in preventing erosion. Therefore, a single factor comes to relieve both conditions which threaten the navigability of streams.

Though the principle of action of vegetation is the same, no matter what the form of vegetation is, the degree of efficiency differs radically. Without question, the forest, of all forms of vegetable growth, is the most efficient in conserving the rainfall and preventing erosion. It keeps the soil in a loose condition, covers the ground with a litter of leaves and branches, and protects the ground surface from the direct rays of the sun and from the full force of rains, all of which is of the highest importance in checking sudden run-off. The leaf canopy overhead breaks the force of heavy rains and allows the water to reach the ground gently and not faster than it can be absorbed. Moreover, the decay of roots and the presence of leaf litter keep the soil porous and capable of absorbing a greater amount of water than when it is bare. The capacity of soil to absorb heavy rainfall such as that of the Southern Appalachians depends largely upon its porosity. In this connection the leaf canopy also plays an important part, since it protects the soil from the rays of the sun which tend to harden the surface and so destroy its absorptive qualities. Forest soil is capable of absorbing a rainfall of several inches with comparatively little run-off, and the water thus absorbed passes to ground storage, to pass off later through springs in seasons when rainfall is lacking. A soil depleted of humus and exposed to heavy rains hardens in structure and erodes rapidly, a condition

which is as unfavorable to the maintenance of navigable streams channels as violent fluctuations in the flow.

The Southern Appalachian forests act as a great storage reservoir, and this is done largely through the medium of its humus, the litter of decomposing vegetable matter which forms the forest floor. It is this which acts like a sponge to absorb the water as it falls. The lowest estimate of the storage capacity of humus made by Ebermayer places it at considerably more than its own weight; and Wiley, from his investigation of Florida muck, gives it about the same capacity, while Wollny, as substantiated by Henry[a] in his laboratory experiments, places it at about four times its own weight. The capacity of humus to absorb moisture depends, moreover, upon its origin. That from hardwoods and spruce has a greater capacity than that from pines. In the actual amount of water absorbed, also, hardwood humus surpasses that of most conifers, since it is deeper. The Appalachian forests are composed largely of hardwoods, and under proper management humus is accumulated to a great depth. At present, frequent fires have in many places reduced or even destroyed it, while excessive cutting of timber has further tended to deplete it by exposing it to the sun and wind.

Though the influence of the forest in promoting the absorption of rain is great, it is even more apparent in the case of snowfall. A large proportion of the winter and early spring precipitation in the Southern Appalachians is in the form of snow. It takes from one day to two weeks longer for this to melt beneath the forest than on fields and pastures. In consequence, the danger from floods through sudden melting is lessened. The tendency is for the snow when it melts to be absorbed by the forest soil and to pass gradually to the streams through subterranean drainage.

The function of the forest and of the humus beneath as a storage reservoir is of high importance, yet in relation to navigation and the storage of storm waters the influence which the forest has in checking erosion is of equal, if not of greater, value. There are few rivers south of Pennsylvania in which sand and silt bars have not been formed by detritus washed from tilled slopes. In the Southern Appalachians, as the population increases and as tilled land on the lower and gentler slopes is destroyed by washing, the steeper slopes are being cleared for farming. Since erosion increases with the slope, this will in the future result in even more rapid erosion with a corresponding increase in the silt burden of the streams. Even on the lesser slopes the erosion from the cultivated heavy red clays and friable loams of the Southern Appalachians is very great. These conditions, therefore, make it absolutely necessary to protect the

[a] Revue des eaux et forêts, 1904, pp. 353 et seq.

forest cover at the sources of all streams if the rivers of the region are to be kept navigable.

The system of channel adjustment which has been largely used in this country to maintain the navigability of rivers has in many cases accomplished great good. It entails, however, an enormous expenditure of money, both in original cost and in cost of maintenance, and, besides, it neither regulates the water supply nor checks erosion. Unquestionably, the method of adjustment by conservation, which has been extensively used in Russia and in France, and partially installed at the head of the Mississippi, will be adopted generally in the United States. This method provides for reservoirs which fill in the spring-freshet season to increase the flow later in the year in time of drought. Floods are checked and sufficient water for navigation at all seasons is provided. By itself, this method would give excellent results in regions where erosion is not a factor. Yet in France it has been found by experience that in mountainous regions the reservoirs gathering water from denuded watersheds become clogged with sand, silt, and gravel and are thus made useless. In the Southern Appalachians this method could succeed in practice only where erosion is prevented by the retention of the forest cover. Erosion inevitably destroys reservoirs and must be checked if the reservoir method is to be effective.

In the storage of water and the equalization of stream flow engineering works will be necessary to cope with the amount of excess water which the forest can not be expected to control, but neither the forest alone nor engineering works alone are sufficient in all cases. The reservoir method depends for its efficiency upon the forest, and without it can not be considered. With the mountain slopes under protection, a system of storage reservoirs properly constructed and controlled would have an almost incalculable effect upon the permanent navigability of the rivers of the Southern Appalachian region.

This report contains the results of a study of most of the navigable rivers of the Southern Appalachian region, and discusses the effect which a system of reservoirs and the preservation of the forest cover would have upon the navigability and general value of these streams.

RIVERS WHICH DRAIN INTO THE ATLANTIC.

The navigable rivers rising in the Southern Appalachian Mountains and covered by this report may be divided into two general systems—those which discharge along the Atlantic coast, and those which discharge into the Ohio River. The first includes the Potomac, James, Roanoke, Great Pedee, Santee, Savannah, Altamaha, and Chattahoochee; the second includes the Monongahela, Kanawha, Little Kanawha, Big Sandy, Kentucky, Cumberland, and Tennessee. The coast rivers are considered first.

The Potomac and James rivers are both tidal to their heads of navigation. In the former Little Falls, just above Washington, effectively bars navigation. In the latter similar conditions exist at Richmond. In each case the mean range of tide at the foot of these falls is about 3 feet. In each there is generally a good depth in the tidal estuary and the benefits derived from the delivery of a large quantity of water during the low-water season are by no means so pronounced as in those navigable portions of rivers to which the tide does not ascend. There is, nevertheless, a well-defined benefit. Channels in tidal estuaries, properly dredged to desired depths, would generally be fairly permanent and of low maintenance cost were it not for material brought down in suspension from the upper drainage area during freshets and deposited in the channels. The increased flow of water scours out the channel at certain places, but freshets of this character generally distribute their disadvantages equally with their benefits. Whenever they scour out one section of channel to the benefit of navigation they also deposit a large amount of material in some other section to its disadvantage. Providing means for storing floods reduces this torrential flow and thereby diminishes and possibly holds back altogether that part of the material that is so injurious to navigable channels in tidal estuaries. The following statement in reference to the James River appears in the Report of the Chief of Engineers, U. S. Army, for the year 1885, Part 2, page 947:

> It has been estimated that at least 275,000 cubic yards of solid matter pass Rocketts Reef in twenty-four hours when there is a freshet not higher than 10 feet. No account is taken in this estimate of the heavy material rolling along the bottom. It is probably far within limits to say that in such a freshet not less than 300,000 cubic yards pass in twenty-four hours. Large quantities of the lighter particles held in suspension are carried far down the river, but the heavier pieces that roll along the bottom move only by a rapid current and stop as soon as the freshet subsides and must be taken out by dredging. It is therefore believed that it will be necessary in the future as it has been in the past to keep on hand a dredging plant ready for emergencies.

This is a significant statement. It means that, year after year, the expense of maintaining and operating a dredging plant must be kept up in connection with James River navigation, and while the cost in any single year may not appear great, a succession of years will produce a total expense far in excess of the cost of providing reservoir capacity sufficient to prevent the silting up of the lower channel. Up to July 1, 1905, the Government had expended in round numbers $1,350,000 on the James River, and the total estimate for the finished improvement of that river is $5,375,000. But, even with this expenditure, high maintenance charges will continue so long as freshets continue to bring down material that must be

dredged from the navigable channel. The same is true of the Potomac River. The conditions upon the drainage areas of both rivers with reference to the possibilities of water conservation may be summarized as follows:

In the Potomac basin, topographic surveys reveal 6 reservoir sites of sufficient capacity for the storage of the entire annual discharge from 1,350 square miles. That is, if these reservoirs were constructed and the gates closed, a year would pass before the water would spill over the tops. These reservoirs would thus place under control 12 per cent of the entire drainage area of the Potomac above Great Falls. Many other reservoir sites might be designated on more careful survey. The total capacity of these reservoirs is 58,510,000,000 cubic feet. The facts concerning them are given in Table 1:

TABLE 1.—*Selected reservoir sites in the Potomac River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
North Fork, South Branch, Potomac River at Petersburg, W. Va.	460	1.12	520	18,550	460	134	7,600
North Fork, South Branch, Shenandoah River, Rockingham County, Va	210	.84	180	6,910	210	92	3,410
North River, Rockingham County, Va	290	1.33	390	14,150	290	96	9,710
Middle River, Augusta County, Va.	180	1.33	240	6,190	140	100	4,250
South Fork, Shenandoah River, Rockingham County, Va	500	1.42	710	2,290	50	40	3,930
Do	200	1.42	280	10,420	200	95	7,150

Similar examination of the James River basin discloses 7 reservoir sites of a capacity sufficient to permit the storage of the mean annual discharge from 2,130 square miles, or 31 per cent of the entire drainage area above Richmond. The facts concerning these reservoirs are given in Table 2:

TABLE 2.—*Selected reservoir sites in the James River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Jackson River, West Bath County, Va.	300	1.18	350	12,400	300	124	5,100
Cowpasture River, Bath County, Va.	280	1.18	330	10,700	280	118	4,300
North River, Rockbridge County, Va.	210	1.18	250	8,620	210	137	5,440
Calfpasture River, southwest Augusta County, Va.	120	1.18	140	4,140	110	100	2,850
James River, Botetourt County, Va.	1,060	1.18	1,250	43,890	1,060	135	18,470
Buffalo Creek, Rockbridge County, Va.	80	1.18	90	3,660	80	113	1,980
Johns Creek, Newcastle, Va.	90	1.18	110	4,620	90	123	3,120

The practical effect of these reservoirs upon navigation in the Potomac and James rivers would be a decrease of 12 per cent in the floods of the Potomac and of 31 per cent in those of the James. As it is the high part of the flood that accomplishes the greatest amount of erosion, it is apparent that the amount of sediment to be taken care of would be decreased by a far greater percentage than the decrease in the height of the floods.

ROANOKE RIVER.

The use of the Roanoke River for navigation fluctuates widely from year to year. Up to June 30, 1905, the United States had expended in the improvement of this river $239,351.75, but the work done has not been effectual in inducing shippers to make extensive use of the channel for transportation. The channel is too precarious to warrant the establishment and maintenance of transportation lines. The Report of the Chief of Engineers, U. S. Army, for 1897, states that only two steamers were plying during the year and that apparently the commerce was rapidly decreasing, inasmuch as eight steamers were making regular trips in 1894.

The Roanoke River flows into the extreme westerly end of Albemarle Sound. The distance from the mouth of the Roanoke to the ocean is 108 miles, and the controlling depth of water 7½ feet. From the mouth of the river up 67 miles to Indian Island Bar the channel at low-water stages exceeds 8 feet in depth. At this bar the depth is diminished from 15 feet to less than 5 feet. Thence, 62 miles to Weldon, the channel is a succession of pools separated by bars of sand, gravel, or rock. The project for improvement contemplates a channel from Hamilton to Weldon, with a width of at least 50 feet and 5 feet deep. The river is subject to frequent and sudden freshets causing recorded rises of 50 feet at Weldon. But during dry seasons the maintenance of a 4-foot channel below Weldon can hardly be accomplished without a greater supply of water. If this were provided, it would secure even a greater low-water depth and would bring about the adjustment of all the navigation difficulties in the river. It should be remembered that a 4-foot channel will not, under modern traffic conditions, permit the passage of boats sufficiently large to compete with railroad transportation. Small shipments are no longer profitable by the water route and therefore a 4-foot channel in the Roanoke would hardly be worth while even if it were properly maintained. Can an extra depth be provided from storage?

Examination of the drainage area shows 4 available reservoir sites of a capacity sufficient to store the mean annual run-off from 1,250

square miles. The facts concerning these reservoirs are set forth in Table 3:

TABLE 3.—*Selected reservoir sites in the Roanoke River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
North Fork, Roanoke River, east Montgomery County, Va.	120	1.23	150	4,820	120	125	2,170
South Fork, Roanoke River, southeast Montgomery County, Va.	110	1.23	140	4,600	110	140	1,790
Goose Creek, Bedford County, Va.	260	1.23	320	10,200	260	106	6,560
Roanoke River, Bedford County Va.	760	1.23	930	29,700	760	150	15,000

The records of the United States Geological Survey, made at its gauging station on the Roanoke River at Neal, N. C., show that the average low-water flow is about 3,000 cubic feet per second. With the run-off from the 1,250 square miles excluded, the ordinary low-water flow at Neal would be 2,600 cubic feet per second. This discharge corresponds to a gauge height of about 2 feet. One of the results of the work of the Geological Survey at Neal, N. C., was the establishment of a rating table for this section of the Roanoke, which shows the amount of water flowing in the channel at each stage of the river from lowest to highest. Therefore, if to the observed flow of the river a certain additional quantity is to be added it is merely necessary to add the additional quantity to the observed flow and consult the rating table to find the height or stage of the river corresponding to the sum of these two. For example, if the Roanoke at Neal is discharging 1,920 cubic feet per second the stage of the river is 1 foot on the United States Geological Survey gauge. Similarly, if 2,580 cubic feet per second are passing through the channel the river is at the 2-foot stage; when the gauge reads 3 feet, 3,280 cubic feet are passing by Neal each second, and so on.

Taking the river at ordinary low stage, the problem is to determine how the stage of the river can be increased by the proper manipulation of the reservoirs above described. Table 4 gives in tabular form the number of days during which the reservoirs would be able to increase the stage of the river to various heights from 1 to 8 feet, the calculations being based upon full, three-quarters-full, and half-full reservoirs.

TABLE 4.—*Roanoke River.*

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cu. ft. per sec.*	*Days.*	*Days.*	*Days.*
1	700	800	600	400
2	1,400	402	302	201
3	2,100	268	201	134
4	2,856	197	148	98
5	3,650	154	115	77
6	4,620	122	92	61
7	5,620	100	75	50
8	6,700	84	63	42

The practical use of this table may be illustrated as follows: With full reservoirs the stage at Neal could be permanently maintained 1 foot higher than low-water flow for a period of eight hundred days. Of course, the river does not remain at the low-water stage for that period of time and therefore some more useful depth could be arranged. The table shows that an additional stage of 4 feet could be maintained for one hundred and ninety-seven days. But this is also an unnecessarily long time. It is found on consultation of the record for the Roanoke that about one hundred and twenty days is the maximum low-water period. This does not mean that the river stays at low water during that entire period. On the contrary, the fluctuations are generally above this stage. But, for the sake of a conservative estimate we will assume a constant low water during the period. A glance at the table will show that with reservoirs full an increase of 6 feet over the low-water stage could be maintained for a period of one hundred and twenty-two days. That is, during this period the river at Neal could be maintained 6 feet higher with the reservoirs than without them.

It might be that in years of little rain the reservoirs would not be filled, but the year would be most exceptional in which they would not receive sufficient drainage for three-quarters of their capacity. Considering the matter on this basis, then, the table shows that an additional stage of 5 feet could be maintained for a period of one hundred and fifteen days, or almost the entire low-water period assumed.

Considering now the very exceptional year, when we will assume that the reservoirs are only half full, it is seen from the table that an additional stage of 3 feet could be maintained for a period of one hundred and thirty-four days or considerably longer than the assumed low-water period, or a stage of 4 feet could be maintained for a period of ninety-eight days.

The remarkable showing made by these estimates will be appreciated by those who are familiar with river navigation, its require-

ments, and difficulties. To provide an additional stage of 6 feet on a river for one hundred and twenty-two days during the low-water season is practically to make the river over, and in the case of the Roanoke it is to change it from a river of shallow and precarious navigation to one in which navigation possibilities will meet all reasonable demands. All this benefit arises from the construction of reservoirs; but it should be remembered in this connection that the benefits to navigation constitute merely one of the advantages arising from the construction of the reservoir system.

Lest anyone unfamiliar with the situation should be deceived, there are certain statements which should be made with reference to the table given above. The additional river stages that will be secured by the discharge of definite amounts of water from storage reservoirs refer to the cross-section at Neal, N. C., alone, except for those places along the river in which the slope and channel capacity are the same as those at Neal. The channel varies in slope and capacity, and, as these increase, a given amount of water will have less effect in adding to the stage of the river; and conversely, as the slope and capacity decrease, the effect of a given amount of water upon the gauge height will be greater. A thorough survey of the channel of the Roanoke River would be necessary in order to determine the effect upon the gauge height at each point in the river, but such information is not necessary in the present broad treatment of the subject. The pilot of a steamboat along a river managed as described above would be thoroughly familiar with the conditions. A given gauge height at Neal or at any point along the stream would indicate to him the depth of water along all the crossings.

In the manipulation of the reservoir system to secure additional navigable depth, the results would be secured through a similarly practical attitude toward the subject. Details are aside from the purpose of this paper. The great point is that the construction of this reservoir system will so increase the value of the Roanoke River as a means of transportation that the cost of the system reckoned upon the most liberal basis will in no wise be commensurate with the benefits conferred.

GREAT PEDEE RIVER.

Navigation on the Great Pedee River will be benefited by the establishment of the proposed National Forest through its principal tributary, the Yadkin, the headwaters of which lie within the area under consideration. Improvements for the benefit of navigation on the Yadkin itself were abandoned by the Government after the expenditure of $102,886, because it was discovered that the portion of the river that had been under improvement was above "another stretch of much more difficult character where the declivity was so great

that its improvement for boats of any character could be accomplished only at very great expense and entirely out of proportion to the benefits." (Report of Chief of Engineers, U. S. Army, 1892, Vol. 2, p. 1435.)

On the Great Pedee itself a depth of 8 feet extends from the mouth of the river to Smiths Mills, a distance of 52 miles. Above this the present project contemplates a channel of 3½ feet to Cheraw, the head of navigation, 172 miles above the mouth. The total expenditure by the Government on the Great Pedee up to June 30, 1905, was $157,460. It is estimated that the project when completed will cost $245,300. Inward freight consists chiefly of general merchandise and fertilizers, and outward freight of rosin, turpentine, tar, cotton, cross-ties, and lumber products, together with rice. In 1904 the tonnage on the river was 162,566, with a value of $1,507,181. According to the records there has been a very general increase in traffic since 1891, especially in the 8-foot channel below Smiths Mills.

The projected depth of not less than 3½ feet at low-water stages from Smiths Mills to Cheraw has not yet been accomplished. Even if it had been, it is difficult to show whence any great benefit would arise. Under present conditions of transportation, boats drawing only from 3 to 3½ feet are of little value as carriers. They can not compete with the poorest kind of railroad transportation. Therefore the expenditure of money along this river to secure merely a 3½-foot stage at low water would seem to be little better than a waste of Government funds. Yet it appears impossible with the present wide range of river stages to secure a greater depth without enormously disproportionate expense, because during low-water periods there is not enough water to produce the desired stage. This is one of the cases in which the extreme value of conserved water, held back during flood seasons in reservoirs in the uplands and judiciously released during low-water seasons, may be appreciated. On the Upper Yadkin River a preliminary survey has revealed many reservoir sites, of which 5 have been selected for the estimates in this paper. The details concerning these reservoirs are given in Table 5:

TABLE 5.—*Selected reservoir sites in the Yadkin River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Yadkin River, Wilkesboro, N. C.	500	2.72	1,360	42,050	480	130	22,600
Yadkin River, above Wilkesboro, N. C.	230	2.72	620	20,300	230	140	10,100
South Yadkin River, Davie County, N. C.	730	2.72	2,000	20,500	230	80	15,600
Deep Creek, Yadkinville, N. C.	120	2.72	330	9,400	110	100	6,600
Ararat River, Surrey County, N. C.	290	2.72	790	5,300	60	100	3,700

It is proposed to show in a manner similar to that already pursued with reference to the Roanoke what may be accomplished by proper reservoir manipulation on the Great Pedee. The discussion is based on the rating table at the cross section of the Yadkin River at Salisbury, N. C., where the Geological Survey has for many years maintained a gauging station. This point is considerably above the head of navigation, and therefore the data can not be applied directly to the navigable part of the river. Unfortunately there is no record of gaugings on the Great Pedee River sufficiently long or comprehensive to serve as the basis of a rating table. The effect of the discharge from reservoirs on the gauge height of the section at Salisbury is not as pronounced as it would be on the lower navigable portion of the river, because of the steep slope along the Salisbury section. Therefore the results, as shown by the following table, are far less favorable to the reservoir proposition than they would be if applied directly to some section in the flatter navigable portion.

The following statement is similar to that previously given with reference to the Roanoke and is subject to the same interpretations: Ordinary low-water flow, 2,000 cubic feet per second; adjusted low-water flow with reservoir area excluded, 1,350 cubic feet per second, equivalent to gauge height at Salisbury of 1.3.

TABLE 6.—*Yadkin River at Salisbury.*

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cubic feet per sec.*	*Days.*	*Days.*	*Days.*
1	1,970	560	420	280
2	4,940	223	167	112
3	8,210	134	100	67
4	11,450	96	72	48

Table 6 shows in general that with full reservoirs there is plenty of water to maintain an added 3-foot stage for an assumed dry weather season of more than four months, or with reservoirs three-fourths full, for an additional 3 feet for more than three months. The effect on the navigable portion of the Great Pedee between Cheraw and Smiths Mills would undoubtedly be more pronounced than this, but, assuming it to be the same, there would be an assurance of a continuous 6-foot stage along this portion of the river instead of the precarious 3 feet now available. A 6-foot channel

would probably fulfill all the demands for navigation in this part of the country and allow the region to develop its transportation facilities to an extent commensurate with its wealth and importance.

SANTEE RIVER.

There are three projects adopted by the Government for the improvement of Santee River navigation. The Santee is formed by the junction of the Congaree and the Wateree rivers, 184 miles above the mouth of the Santee. The three projects united involve the improvement of the river up to Columbia on the Congaree and up to Camden on the Wateree, and provide for continuous 4-foot navigation throughout the entire distance. Up to June 30, 1905, $286,189 had been expended, while the approximate estimate for completion is $456,763.

Navigation on the main stream appears to be increasing. During the calendar year 1904 there were transported 242,800 tons, with a value of $1,652,000. There is every reason to believe that throughout the entire length of the main stream the transportation would be greater if a deeper channel could be provided and its maintenance assured. It will, therefore, be of interest to show how the depth during low-water seasons may be increased by conservation of flood waters in the basin of the Catawba River, which is the principal tributary of the Wateree. Inasmuch as the drainage area of the Congaree River lies outside of the proposed Southern Appalachian National Forest, no figures have been secured concerning its conservation possibilities. The effects of conservation at the headwaters of the Catawba River alone must be considered, but it should be remembered that in so doing we are taking into account only a part of the possibilities for improving navigation along the Santee.

Wateree.—In considering the added depth which will be gained by the proper use of these reservoirs it is necessary to consider the cross section of the Wateree River at Camden, where the United States Geological Survey has for many years maintained a gauging station and established a rating table. The relation of this section to sections below on the Santee are similar to those already discussed with reference to the Yadkin. The slope of the river at Camden is steeper than the general slope along the Santee, and although the Santee channel is of greater capacity the relation between this capacity and the rise of gauge height with increased flow is not proportional. It may be safely stated that the increase of 1 foot on the gauge at Camden, due to the influx of a certain quantity of water, will produce an equal, if not a greater, increase in the stage of the Santee River.

In the drainage area of the Wateree, 3 reservoir sites may be found of a capacity sufficient to store the entire annual flow from 720

square miles. Detailed facts concerning these sites are set forth in Table 7:

TABLE 7.—*Selected reservoir sites in the Wateree River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Catawba River, northwest Mecklenburg County, N. C.	420	1.64	700	24,970	420	77	18,250
Catawba River near Hickory, Catawba County, N. C.	600	1.64	980	9,870	190	100	7,760
Catawba River west of Morganton, N. C.	480	1.64	790	5,380	100	75	4,920

The ordinary low-water flow of Wateree River at Camden is about 3,000 second-feet. If the conserved area of 720 square miles be deducted from this, the low-water flow will be about 2,200 second-feet. The following table shows, in a manner similar to that for the rivers discussed in preceding pages, what may be accomplished at Camden by intelligent manipulation of reservoirs.

TABLE 8.—*Wateree River.*

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cubic feet per sec.*	*Days.*	*Days.*	*Days.*
1	870	495	370	248
2	1,770	240	182	140
3	2,710	159	120	80
4	3,755	115	86	58
5	4,705	92	69	46
6	5,655	76	57	38

From Table 8 it may be seen that with a full reservoir capacity the stage of Wateree River at Camden can be increased 6 feet for a period of seventy-six days, or 3 feet for a period of one hundred and fifty-nine days. Considering the low-water period at an average of about four months, it will be seen that, reckoning on full reservoir capacity, the stage of Wateree River throughout such a period could be increased 4 feet by intelligent delivery from storage. The value of an added 4 feet to the stage of Wateree and Santee rivers and the guaranty of free and open navigation throughout the year can readily be appreciated by the people living in the valley of the Santee.

SAVANNAH RIVER.

The Savannah River is navigable from its mouth up to Petersburg, a distance of 48 miles above the city of Augusta. That part of the river above Augusta is not well adapted to open navigation because of its steep slope, while that part below Augusta has all the possibilities of a valuable highway. The river, as a whole, presents one of the best cases to demonstrate that the conservation of water and

its proper manipulation may under certain conditions be far more effectual in maintaining navigable depths than any of the measures that have been included in the method of channel adjustment. Here is a river which, during the greater part of the year, is navigable for steamboats drawing from 4 to 5 feet of water, but which during low-water seasons is marked by shoals in its upper portion with low-water depth of not more than 3 feet. The improvement of this river, as outlined in the Report of the Chief of Engineers, U. S. Army, for 1890, is to be accomplished by removing sand and gravel bars, regulating portions of the river, revetting banks, and inclosing incipient cut-offs.

In pursuance of this plan the United States had expended up to June 30, 1905, the sum of $517,643, of which $58,935 was expended upon the river above Augusta. The estimate of the cost for completion of the present project is $645,045. The expenditures in the upper portion of the river have been suspended because the experience gained showed that a comprehensive plan for permanently improving this portion of the river would involve an expenditure of funds entirely out of proportion to the prospective commercial benefits. Therefore, navigation development in the Savannah River has been confined to that portion below the city of Augusta.

It is of interest to determine the effect of the proposed system of reservoirs on the navigation possibilities in the Savannah River. From topographic surveys already made 14 reservoir sites have been selected, the total capacity of which equals the run-off from 1,670 square miles of drainage area, which is equivalent to 23 per cent of the entire drainage area above Augusta. The facts concerning these reservoir sites are given in Table 9:

TABLE 9.—*Selected reservoir sites in the Savannah River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cu. ft.*	*Square miles.*	*Feet.*	*Acres.*
Keowee River, Pickens County, S. C.	270	3.45	930	25,130	230	150	11,240
Little River, Oconee County, S. C.	90	3.45	310	8,480	80	100	5,820
Twelvemile Creek, Pickens County, S. C.	160	3.45	550	2,210	20	50	3,030
Twenty-three Mile Creek, Anderson County, S. C.	150	3.45	520	15,370	140	70	6,620
Conneross Creek, Oconee County, S. C.	80	3.45	280	1,700	20	50	2,330
Tugaloo River, southwest Oconee County, S. C.	260	3.45	900	11,870	110	100	8,140
Chattooga River, west Oconee County, S. C.	120	3.45	410	9,470	90	150	3,310
Do	190	3.45	660	15,920	140	150	4,690
Tallulah River, Rabun County, Ga.	130	4.35	570	2,440	20	90	1,860
South Fork River, Oglethorpe County, Ga.	260	1.89	490	1,940	30	50	2,660
Broad River, Madison County, Ga.	440	1.89	830	28,590	440	98	17,850
Hudson River, Banks County, Ga.	180	1.89	340	4,680	80	50	6,420
Beaver Dam Creek east of Elberton, Ga.	110	1.89	210	7,030	110	98	3,900
Rocky River, near Lowndesville, S. C.	240	1.89	450	9,680	160	100	6,580

Assuming that these reservoirs have been constructed and that they have been filled with flood waters which, in the present unrestrained state, do so great damage along the Savannah, what will be the effect in the cross section of the river at Augusta if the water is allowed to escape during the low-water season? The long series of records obtained by the United States Geological Survey at Augusta makes the determination of this point extremely simple. The results are embodied in Table 10, which shows the periods during which increased depth could be maintained at Augusta.

TABLE 10.—*Savannah River.*

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cubic feet per sec.*	*Days.*	*Days.*	*Days.*
1	690	2,260	1,700	1,130
2	1,770	920	690	460
3	3,130	520	390	260
4	4,650	350	263	175
5	6,270	260	195	130
6	7,990	204	153	102
7	9,810	166	124	83
8	11,730	139	104	70
9	13,750	118	89	59

The facts indicated in Table 10 are the most remarkable yet presented. The amount of water that may be stored in these reservoirs is sufficient to maintain an added depth of 9 feet at the Augusta cross section for a period of one hundred and eighteen days, which is equivalent to an assumed low-water season of four months. Even if the reservoirs were only one-half full at the beginning of the low-water season there would still be an amount of water sufficient to add an additional 5 feet to the river for a period of one hundred and thirty days. The reservoir capacity set forth in Table 10 is probably greater than it would be necessary or economical to build. It is not the function of this paper to determine upon the proper capacity for development. On the contrary, the aim is to show only a part of the possibilities of water conservation. Neither in the case of the Savannah nor any other river discussed in this paper have the examinations been sufficiently extensive to give all the possibilities. Having discovered and verified a sufficient number for the purposes in view, the search has been discontinued. It should be remembered, also, that these possibilities are not confined in their application to the benefits to navigation, but extend to the prevention of floods, to the increase of water power and to all the other useful purposes to which water is put.

The Savannah River is an important stream commercially. During the year 1904 seven steamers were engaged in river traffic, making 300 round trips between Savannah and Augusta and carrying 61,353 tons of freight. There were also received at Savannah from this river in small boats and lighters 107,000 bushels of rice, valued at $82,600, and timber valued at $330,000. But the stretch between Savannah and Augusta would become a far more important artery of commerce than it is if a good navigable depth could at all times be assured.

ALTAMAHA RIVER.

Navigation on the Altamaha River and its tributaries covers 480 miles; 131 miles from the mouth to the junction of the Oconee and Ocmulgee rivers, 147 miles up the Oconee to Milledgeville, and 202 miles up the Ocmulgee to Macon. The Oconee at ordinary stages is navigable only to a point about 25 miles above Dublin, Ga., or a distance of 104 miles from the confluence, while the Ocmulgee during recent years has not been navigable, except at high water, above Hawkinsville, a distance of 133 miles from the confluence.

Navigation on the Altamaha consists largely of the rafting of lumber. During 1904 109,000,000 feet, valued at $1,350,000, passed down the river. The majority of this timber came from the Oconee and Ocmulgee rivers, though about 49,000,000 feet originated on the Altamaha. There were also 4,500 tons of freight, valued at $200,000.

The present project of the Government for the improvement of the Altamaha River provides for the establishment of a channel 3 feet deep at summer low water, to be accomplished by removing shoals and sand bars, building deflecting dikes, and inclosing incipient cut-offs. The amount expended on the work under the present project was, up to June 30, 1905, $74,362, of which $9,000 was for maintenance. This added to the amount previously expended gives a total of $144,139. The estimated cost of the completion of the project is $259,000.

Oconee.—On the Oconee River the present Government project provides for the establishment of a navigable channel 3 feet deep at ordinary summer low water from Milledgeville to the mouth, at a cost estimated at $171,000. The amount expended on this project to June 30, 1905, was $153,808. In 1904 the amount of freight was 32,160 tons, valued at $443,225. In addition to this, 60,000,000 feet of lumber were rafted down the stream. In spite of all expenditures the summer low-water depth is about 2½ feet between the forks and a point 25 miles above Dublin, and 1½ feet between this point and Milledgeville. The river occasionally falls below this stage and frequently rises to 20 feet above it.

Consideration will here be given only to the main stream and the Oconee, because the surveys made under the Appalachian National Forest project do not include the headwaters of the Ocmulgee, in which region there are many good reservoir sites which, if developed, would probably have as great beneficial effects on the main stream as those now to be discussed on the Oconee. Table 11 shows the reservoir sites which have been selected in the Oconee drainage basin.

TABLE 11.—*Selected reservoir sites in the Oconee River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Oconee River, Jackson County, Ga.	170	1.18	200	8,260	170	74	6,870
Middle and Mulberry Forks, Jackson County, Ga.	340	1.18	400	13,520	340	98	6,290

The two enormous reservoir sites set forth in Table 11 will conserve the mean annual discharge from 510 square miles of drainage area, and the total storage capacity will be 21,780,000,000 cubic feet. The Geological Survey has for many years maintained a station on the Oconee River at Dublin. The discharge of water from these reservoirs at different rates and under different conditions and the effects upon the river stage at that point are given in Table 12:

TABLE 12.—*Oconee River.*

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cubic feet per sec.*	*Days.*	*Days.*	*Days.*
1	475	460	346	230
2	1,130	194	145	97
3	1,840	119	89	60
4	2,610	84	63	42
5	3,510	62	47	31

CHATTAHOOCHEE RIVER.

On the Chattahoochee River conditions are similar to those along other coastal streams which have been considered. The difficulties are lack of navigable depth at low-water seasons of the year, in spite of the expenditure of large sums of money by the Government. No increased depth has been gained, and each season has brought in greater quantities of sand, filling the original river bed and gradually

changing its regimen. It is the endeavor to maintain a 4-foot draft at ordinary low water, but during some seasons a scant 3 feet can be carried. It is apparent, then, that the greatest need along the Chattahoochee is extra depth. Sufficient water can be stored in upland reservoirs to provide this. There are many good reservoir sites in the Chattahoochee basin; but of these, four are especially recommended. Their locations and characteristics appear in Table 13:

TABLE 13.—*Selected reservoir sites in the Chattahoochee River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Chattahoochee River north of Gainesville, Ga.	350	2.34	820	24,360	320	140	11,110
Chestatee River northwest of Gainesville, Ga.	140	2.34	330	10,640	140	100	7,300
Chestatee River east of Dahlonega, Ga.	150	2.34	350	3,300	40	100	2,260
Chattahoochee River east of White County, Ga.	110	2.34	260	5,520	70	100	3,790

The mean annual flow from 570 square miles can be entirely retained in these reservoirs. This amounts to 17 per cent of the entire drainage area above West Point. The effect of the discharge of water from these reservoirs during low-water seasons has been measured along the section of the river at West Point where a gauging station is maintained by the United States Geological Survey. It should be noted that the West Point station is in a steep portion of the stream and that the increase of stage here with a given quantity of water is not as great as it would be along the flat navigable part of the river below Columbus, Ga. Table 14 contains figures concerning the increase of stage at West Point:

TABLE 14.—*Chattahoochee River.*

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cubic feet per sec.*	*Days.*	*Days.*	*Days.*
1	1,150	430	324	215
2	2,800	177	133	88
3	5,050	98	74	49
4	8,054	62	46	31

This completes the consideration of those Atlantic coast and Gulf rivers which collect a considerable part of their water within the area

proposed as the Southern Appalachian National Forest. It will be seen that transportation on some of these rivers has been maintained in spite of the fact that at certain places navigable stages can not be guaranteed throughout the year. On other rivers traffic has waned because it has been found impossible or too expensive to maintain the proper navigable stage throughout the year. The regions traversed or drained by these rivers have, therefore, never had an opportunity to show how they might develop under an open system of navigation that could be depended on and that would encourage the construction and operation of modern steamboat lines.

RIVERS WHICH DRAIN INTO THE OHIO.

The problem of maintaining navigable depth in streams heading on the western slope of the Southern Appalachian Mountains is somewhat more complex than in those flowing from the eastern side. When the conserved water on the eastern side has fulfilled its purpose of maintaining navigation on the coastal streams during low-water seasons it passes into the Atlantic Ocean and is of no further use to inland shipping. When the stored water on the western slope has served the same purpose it passes into the Ohio River, thereby continuing its usefulness throughout the entire navigable length of that stream and even down into the Mississippi. It is necessary, therefore, not only to consider the various tributaries of the Ohio in the manner heretofore pursued, but their combined effect upon the main stem of the Ohio as well.

No treatment of water supply and navigation in the Ohio can be complete unless the Allegheny and the other northern tributaries are considered, but as their basins lie beyond the area of the proposed National Forest the scope of this paper must be confined to the southern tributaries.

MONONGAHELA RIVER.

The Monongahela River joins the Allegheny at Pittsburg to form the Ohio. Its channel is canalized from its mouth up to Fairmont, W. Va., the slack-water system comprising 15 dams and 19 locks. The 89 miles of channel in Pennsylvania was in its original condition prior to 1840 navigable for steamboats only at high stages, while that part in West Virginia was, in its original condition, impeded at high water by a swift current due to a fall of about 2 feet per mile. At low stages it was obstructed by shoals and numerous gravel and rock bars. Steamboat navigation was practicable at high stages as far upstream as Morgantown, W. Va.

The old Monongahela Navigation Company improved the river from Pittsburg to the West Virginia State line by building 7 locks

and dams for slack-water navigation. The United States continued the improvement above the highest dam of this company and completed the project in November, 1889, with the result that boats drawing 5.2 feet of water could navigate in low stages as far upstream as Morgantown, W. Va. Further national improvement consisted of the construction of 6 more locks and dams, Nos. 10 to 15, inclusive, extending from Morgantown to Fairmont, W. Va. Subsequently the United States purchased the property of the Monongahela Navigation Company for $3,766,615, and the total cost for improvement of Monongahela River up to June 30, 1905, including this purchase money, was $6,023,605. For maintenance of these locks and dams up to June 30, 1905, the United States had paid $1,694,384, and the amount expended during the fiscal year ending at that date was $234,070.

From 1902 to 1905, inclusive, the tonnage carried on the Monongahela amounted to 9,500,000 annually, except in 1903, when the total was 11,369,814 tons, but during this period the passenger traffic steadily declined.

The Monongahela is formed a short distance above Fairmont by the junction of the Tygarts Valley River and the West Fork. The former stream drains an area of about 1,390 square miles of rugged country. The valley is valuable in mineral and timber products, but the excessive fall of the channel precludes the hope that it will be developed for navigation. West Fork, the other affluent, is comparatively sluggish and has practically the same slope as the Monongahela above the Pennsylvania line. Therefore it is readily adapted for navigation as far as Clarksburg, W. Va., with the depth which can be easily maintained at low water, either by the method of channel adjustment or by conservation. One-half the flow of the West Fork can be controlled, which would maintain the river at an almost constant stage throughout the year.

The Monongahela system of locks and dams was constructed, so far as public records show, without any suitable investigation of the possibilities of maintaining navigable stage in the river by conservation of flood waters. The idea that it might be possible to maintain navigable stage during low-water seasons by saving some of the water wasted during spring floods appears not to have been considered. The dams were constructed in the face of the knowledge that maintenance charges would be heavy and would continue generation after generation. The fact that they might be used for power development if sufficient summer flow were provided and so become self-supporting seems not to have made a strong impression. If this possibility had been taken into account it would not have been necessary to construct as many locks and dams as now exist along the

river. The entire system up to Morgantown might have been abolished, as can be shown by information at hand.

There are in the Monongahela River basin eleven reservoir sites of a capacity sufficient to store the entire mean annual flow from 1,950 square miles. Detailed facts concerning these reservoirs are set forth in Table 15:

TABLE 15.—*Selected reservoir sites in the Monongahela River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Dunkard Creek, Monongahela County, W. Va.	160	1.7	270	8,300	150	100	5,800
Buffalo Creek, Mannington, W. Va.	40	1.7	70	2,400	40	59	2,100
Booths Creek, Monongah, W. Va.	40	1.7	70	2,800	40	101	1,600
Sandy Creek, Grafton, W. Va.	80	1.7	140	6,200	80	155	3,600
Teter Creek, Nestorville, W. Va.	40	1.7	60	2,600	40	115	1,300
Elk Creek, Clarksburg, W. Va.	100	1.7	170	5,900	100	92	4,500
West Fork River, Clarksburg, W. Va.	380	1.7	640	24,700	380	109	15,900
Buckhannon River, Buckhannon, W. Va.	310	1.7	530	18,800	310	77	13,300
Middle Fork Tygart, Barbour County, W. Va.	140	1.7	230	8,100	140	107	4,300
Cheat River, Tucker County, W. Va.	820	1.7	1,400	23,800	440	200	6,600
Tygart River, Beverly, W. Va.	330	1.7	560	19,100	330	142	10,000

With the above reservoirs in operation, the entire flow from 2,050 square miles, or 35 per cent of the drainage area of the Monongahela above the mouth of the Youghiogheny, can be cut out of the drainage system for a year, or, in other words, they can retain an entire year's flow from that area until such a time as the conditions on the lower river make it necessary to use the water for purposes of navigation. In order to show what additional depth might be maintained on the Monongahela, three sections have been sounded, measured and rated, so that the effect of discharge on the stage of water may be accurately determined. These sections are as follows: First, about one-half mile below the bridge at Morgantown, W. Va.; second, at Brownsville, Pa.; third, below McKeesport, Pa. These sections were chosen so as to cover the extreme and average ranges of slope in the canalized portion of the river below Morgantown.

Table 16, similar to those already presented, shows what may be accomplished in the Monongahela by proper manipulation of storage reservoirs.

TABLE 16.—*Monongahela River.*

SECTION BELOW MORGANTOWN BRIDGE.

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cubic feet per sec.*	*Days.*	*Days.*	*Days.*
1	545	1,650	1,240	825
2	1,290	700	525	350
3	2,300	392	293	196
4	3,600	250	188	125
5	5,030	179	134	90
6	6,760	133	100	66

SECTION AT BROWNSVILLE, PA.

1	730	1,740	1,300	870
2	1,700	730	550	365
3	3,070	410	310	205
4	4,670	270	203	135
5	6,570	193	145	96
6	8,730	139	104	70

SECTION BELOW McKEESPORT, PA.

1	1,080	1,500	1,120	750
2	2,470	650	490	325
3	3,940	410	310	205
4	5,840	280	210	140
5	8,000	200	150	100
6	10,340	156	117	78

Table 16 may be interpreted thus: A stage of water in the Monongahela 6 feet additional to that caused by the normal dry season flow may be maintained throughout the longest dry season ever known in the history of the river. The money used for slack-water navigation might better have been spent in the hills, but now that the dams are erected the proper course is to reserve the Monongahela highlands and to produce profitable power on these dams so that the system will be self-supporting.

Youghiogheny.—The Youghiogheny is the most important tributary of the Monongahela. Its drainage basin lies within the State of Pennsylvania and comprises 1,750 square miles. It joins the Monongahela at McKeesport, 15 miles above the Ohio.

Navigation on the Youghiogheny has given considerable trouble in the past. About 1850 a company was chartered by the State of Pennsylvania to build 2 locks and dams to carry the slack water 12 miles to Alpsville. The lock had lifts of from 12 to 15 feet, but the structures were not well built, traffic was small, and they were finally destroyed by floods and ice. The report of the Chief of Engineers, U. S. Army, for 1900 recommends the extension of the slack-water navigation as far up as Connellsville. The proposition involves the

construction of locks and dams at the head of Little Falls, at the head of Middleshoot, and at the rapids above Great Falls. The total cost of these 3 locks and dams was estimated at about $600,000.

Along the entire length of the Youghiogheny, from its mouth to Connellsville, there are heavy deposits of bituminous coal, and Connellsville is the center of the coke and iron district. The Ohio River affords a convenient outlet for these products. The prospective annual river tonnage, exclusive of coal, is estimated to amount to something like 75,000 tons, and it is further estimated that a Youghiogheny slack-water system would take not less than 40 per cent of the coal lying near the river away from the railroads. The output in 1898 was 1,576,097 tons.

The great difficulty in the way of the development of the Youghiogheny arises from the steep slope of the channel, and, more important, the exceedingly small supply of water during summer and fall. In 1904 the minimum run-off of the Youghiogheny at Connellsville was only about 59 cubic feet per second. Out of the 93 days during the last three months of the year the river discharged less than 150 cubic feet per second for 87 days.

Table 17 gives facts concerning selected reservoirs in the Youghiogheny basin. The area covered does not include the tributary basins of Laurel and Castleman's rivers, which comprise 32 per cent of the entire Youghiogheny drainage area. Rapid reconnaissance of these tributaries shows them to be at least as well supplied with reservoir sites as the Upper Youghiogheny itself.

TABLE 17.—*Selected reservoir sites in the Youghiogheny River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Youghiogheny River, Friendsville, Md	270	2.47	690	20,270	255	240	4,220
Deep Creek, Garrett County, Md	55	2.47	136	4,603	55	83	3,200
Cherry Creek, Garrett County, Md	55	2.47	136	4,912	55	64	3,930
Muddy Creek, Garrett County, Md	13	2.47	32	1,065	13	70	1,100
Herrington Creek, Garrett County, Md	13	2.47	32	900	11	60	700

Table 17 shows that the storage capacity is not sufficient to provide a navigable stage in Youghiogheny River during the low-water season, and it is doubtful whether if the additional storage on the unsurveyed portions of the basin were taken into account there would be a sufficient supply for this purpose. The course of the river below Connellsville is fairly steep, and here is presented one of the cases in which canalization is apparently the only solution. In connection with the plans for such work, it will be well to consider

the possibility of making this slack-water system pay for itself by utilizing the excellent power possibilities that will be made available at the dams. The part of the river that it is proposed to canalize is in the midst of a great center of industry, and the power derived would find a ready market at prices that would make the investment remunerative. There is presented here a condition identical with that on the Monongahela before canalization, but here there is the added advantage that the proposed Youghiogheny system is a new one and no mistake need be made. The way to utilize the available power along this stream is to develop coincidently with canalization the conservation system outlined in Table 17 and to provide that the upland area shall be set apart as a reserve, so that the natural conditions of forestation will not be destroyed.

The dams constructed for slack-water navigation, according to the plans that have been approved by the Chief of Engineers, U. S. Army, will afford a total fall of 30 feet. The minimum flow for the six highest months along this portion of the Youghiogheny is about 1,000 cubic feet per second, while the water from the above-mentioned reservoirs if distributed over twelve months would be about 950 cubic feet per second. Considering only the minimum flow for the six highest months and the proper manipulation of the water in storage, there would be insured a discharge of at least 1,500 cubic feet per second throughout the year at the various dams proposed under the slack-water system. This amount of water, allowing for necessary loss by leakage and lockage, would insure the production of 4,100 horsepower, which would at times be greatly exceeded. Figuring on an average rental of $20 per horsepower per year (it would be considerably greater in this situation), the total income would be $82,000, which represents an interest of 3 per cent on about $2,700,000.

This provides a specific illustration of the policy that should prevail in connection with improvements for inland navigation. Under it water and power now wasted would be put to productive use and the cost of the canalization and conservation would be returned, in marked contrast to the present policy, which involves a constant drain on the National Treasury.

KANAWHA RIVER.

The project for improvement of navigation on Kanawha River, adopted in 1875, provided for maintaining a depth of 6 feet throughout the year over a distance of 96 miles from its confluence with the Ohio. For 79 miles, or from the confluence up to Paint Creek, this was accomplished by 8 movable dams and for the remainder of the distance by 2 fixed dams. These dams have been completed and are now in operation. Up to June 30, 1905, the United States had expended $4,124,526 for improvement and $656,986 for care and operation, the

latter expense increasing annually. The commerce on the river for the calendar year 1905 amounted to 1,613,899 tons, with a valuation of $6,865,521, against 1,233,153 tons, with a valuation of $7,899,000, for the year 1904.

It is proposed to show what the effect would have been on the original bed of Kanawha River, before the introduction of the present canalization system, had the possibilities for conservation been utilized, and to show that the great expenditures for canalization might have been avoided and a large part, at any rate, of the money so expended used for the construction of reservoirs in the mountains. The problem is similar to that just considered on the Monongahela.

Topographic survey of the Kanawha drainage area reveals 17 reservoir sites having a storage capacity of 280,750,000,000 cubic feet, sufficient to retain the annual run-off from 5,180 square miles in the drainage area, or about 43 per cent of the entire basin. Detailed facts concerning these reservoir sites are set forth in Table 18:

TABLE 18.—*Selected reservoir sites in the Kanawha River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Greenbrier River, Pocahontas County, W. Va.	320	1.44	460	16,300	320	177	4,700
Elk River, Clay County, W. Va.	940	1.44	1,350	49,900	940	190	15,700
Greenbrier River, Lewisburg, W. Va.	680	1.44	960	32,900	680	164	11,600
Meadow River, Greenbrier County, W. Va.	180	1.44	250	8,000	180	80	7,000
Muddlety Creek, Nicholas County, W. Va.	60	1.44	90	3,400	60	74	2,600
Blue Creek, Kanawha County, W. Va.	60	1.44	90	3,300	60	97	2,300
Gauley River, Fayette County, W. Va.	1,290	1.44	1,860	35,900	780	250	7,500
New River, above mouth Greenbrier River	3,600	1.6	5,750	20,300	390	135	8,000
Walker Creek, Giles County, Va.	310	2.02	620	6,550	100	110	3,000
New River, Radford, Va.	1,740	2.02	3,500	59,400	920	125	23,000
Reed Creek, Wythe County, Va.	250	2.02	510	6,400	100	100	4,500
Big Reed Island Creek, Pulaski County, Va.	380	2.02	770	4,000	60	100	2,800
Cripple Creek, Wythe County, Va.	180	2.02	370	2,900	40	100	2,000
New River, Carrol County, Va.	1,290	2.02	2,600	19,400	300	200	6,200
Eighteen-Mile Creek, Putnam County, W. Va.	60	1.3	80	4,000	60	63	2,360
Thirteen-Mile Creek, Mason County, W. Va.	80	1.3	100	3,400	80	61	2,000
Pocotaligo River, Putnam County, W. Va.	230	1.3	300	4,700	110	65	3,900

For the purpose of determining the effect of this storage upon the stage of Kanawha River, two sections have been surveyed and rated so that the effect of increased discharge on gauge heights in the channel can be accurately determined. These sections are located one above Lock No. 6, where the natural slope was fairly steep for this part of the river, and one below the mouth of Elk River, where the slope

was very slight. The effects of discharge from storage at various rates upon the stages of these two sections are set forth in Table 19:

TABLE 19.—*Kanawha River.*

SECTION ABOVE LOCK No. 6.

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cubic feet per sec.*	*Days.*	*Days.*	*Days.*
1.....	1,570	1,860	1,400	930
2.....	3,420	850	640	425
3.....	5,680	514	380	257
4.....	8,400	347	260	174
5.....	11,400	256	192	128
6.....	14,800	197	148	98
7.....	18,300	160	120	80

SECTION BELOW ELK RIVER.

(About 2½ miles above Lock No. 6.)

1.....	700	4,170	3,100	2,085
2.....	1,630	1,790	1,340	895
3.....	2,650	1,100	830	550
4.....	3,710	790	590	395
5.....	5,000	580	440	290
6.....	6,400	460	340	230
7.....	8,000	365	270	182

From Table 19 it is seen that the storage proposed on the upper drainage area is sufficient to prolong at the steeper section an additional 7-foot stage for a period of one hundred and sixty days with reservoirs full, or one hundred and twenty days with reservoirs three-fourths full, while at the flat section below the mouth of Elk River the effect is far more marked and the additional discharge of 8,000 cubic feet per second raises the stage 7 feet. The possibilities along this portion of the river for the maintenance of stage by stored waters are so great that it is evident that the installation of the expensive lock and dam system was unnecessary throughout that portion, at least, in which the movable dams have been installed.

It is necessary to omit from this paper consideration of the effects of the proposed National Forest on navigation in the Big Sandy, Kentucky, and Cumberland rivers. The greater part of the headwaters of the Big Sandy and smaller portions of the headwaters of the other two streams are included within the proposed area and therefore their effects upon navigation are a legitimate consideration in this paper, but, unfortunately, the surveys available and the records of stream flow are not sufficiently complete to serve as a basis.

TENNESSEE RIVER.

The Tennessee River forms a system of internal waterways navigable by steamboats for more than 1,300 miles. The main river, formed by the junction of the French Broad and Holston rivers, 4½ miles above Knoxville, Tenn., is 652 miles long. Throughout the year the river is navigable from the mouth to Riverton, Ala. Just above Riverton, at Colbert and Bee Tree shoals, a lateral canal 8 miles long is under construction. Another canal 3 miles long is projected at Little Muscle Shoals, just above Florence, Ala., and the Muscle Shoals canal crosses the Big Muscle and Elk River shoals. There is now no through traffic covering the entire year. The longest regular boat service is that between Chattanooga and Paducah.

In the year 1904 the tonnage amounted to 1,607,000, valued at $30,000,000. The amount allotted for Tennessee River improvements and canals up to June 30, 1905, was $7,170,000. Of this sum $913,419 was spent for operation, care, and repair of Muscle Shoals Canal from November 30, 1890, to June 30, 1905.

The improvement of the river has been carried on in three sections—first, that part of the river above Chattanooga, Tenn.; second, that lying between Chattanooga and Riverton, Ala., and, third, that from Riverton to the mouth. The character of these improvements is as follows:

First section: above Chattanooga.—The attempt here is to obtain by training walls, wing dams, and dredging a low-water channel of 3 feet from Chattanooga to the mouth of French Broad River, at an estimated cost of $650,000. The maximum draft that can be carried at mean low water over the shallowest places in this section is about 18 inches, and the extreme flood oscillations range from 40 feet at Knoxville to 58 feet at Chattanooga. The very small depth at mean low water and the enormous range of stage in the river are quite suggestive of what might be accomplished in the maintenance of a high navigable stage if a part of the flood waters could be held back and distributed through the low-water season. It has been demonstrated that the desired 3-foot stage will not encourage any great amount of water transportation along this section of the river, because, as has been said in this paper, transportation conditions are such that small-draft boats can not be operated with profit. A later paragraph will show what may be accomplished by means of storage reservoirs.

Second section: between Chattanooga and Riverton.—This section was originally obstructed between Chattanooga and Browns Ferry by bars, bowlders, and reefs. Navigation is possible on this section from six to nine months annually. Between Florence and Riverton, Colbert and Bee Tree Shoals prevent navigation six months in the

year, but, as explained in a preceding paragraph, this obstruction is to be overcome by canalization. The present project provides for a lock and dam to be built, mainly by private parties, 33 miles below Chattanooga, forming a pool that will extend to that city with a depth of at least 6 feet at low water, together with the construction of a lateral canal about 8 miles long with one lock. The total amount spent on this section of the river, from Chattanooga to Riverton, up to June 30, 1905, was $1,550,000. Although there is greater need for canalization along the second than along the first section because of the existence of abrupt falls, there are long stretches of the river in which the slope is very gradual and in which the conditions for improvement by the release of conserved waters during the low-water season are ideal. The effect of such discharge will be noted in a later paragraph.

Third section: from Riverton to Paducah.—This part of the river has a moderate and uniform slope with original low-water depth of about 3.5 feet over its lower 196 miles and 2 feet over the remainder of the distance to Riverton. The present project is to obtain, by dredging, a channel not less than 5 feet deep. The total amount expended to June 30, 1905, was $279,663. The extreme flood oscillations at Jacksonville are 48 feet and at Paducah 55 feet. The commerce along the river between Florence and Paducah during the year 1904 amounted to 871,380 tons.

It will be noted that this flat section of the river, which is subject to such great oscillations by reason of flood discharge, is entirely subject to convenient regulation if the necessary water can be provided from storage. It will also be noted that the 5-foot channel is to be secured and maintained by dredging, which means continual work and large maintenance expenses for the purpose of removing the silt and gravel that will be deposited in the channel each season. The defects are subject to correction by the maintenance of uniform flow of sufficient amount to secure a desired stage. Such an amount of water would also produce a uniform deposition of gravel, and eventually a proper slope and capacity for the discharge would be effected, so that a permanent channel could always be depended upon.

The storage possibilities in the upper part of this basin which it is proposed to include in the National Forest are set forth in Table 20. It will be noted that the total storage is considerably greater than will be necessary to effect the improvement advocated; but as the purpose of this paper is to show possibilities rather than to present finished plans for improvement, no estimate has been made of the precise storage desired or needed.

TABLE 20.—*Selected reservoir sites in the Tennessee River basin.*

Stream and location.	Catchment area.	Mean annual run-off per square mile.	Flow available.	Capacity of reservoir.	Capacity of reservoir in catchment area.	Height of dam.	Area of flow line.
	Square miles.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*1,000,000 cubic feet.*	*Square miles.*	*Feet.*	*Acres.*
Clinch River, Scott County, Va.	780	1.38	1,080	30,400	690	180	10,000
Nolichucky River, Greenville, Tenn.	940	1.69	1,590	14,700	270	100	10,200
Clinch River, Sneedville, Tenn.	560	1.38	770	18,500	390	100	8,500
Powell River, Jonesville, Va.	570	1.38	790	17,100	380	100	12,000
Holston River, northeast of Knoxville, Tenn.	3,400	1.56	5,300	163,500	3,300	160	49,000
French Broad River, east of Knoxville, Tenn.	4,050	1.56	6,300	199,600	4,000	200	70,000
Little River, south of Knoxville, Tenn.	290	1.56	450	17,400	290	94	12,100
Little Tennessee River, Loudon County, Tenn.	2,520	2.78	7,000	78,000	860	100	54,400
Little Tennessee River, Swain County, Tenn.	380	2.78	1,050	7,340	80	100	5,120
Clinch River, Roane County, Tenn.	2,110	1.38	2,900	26,500	600	60	20,000
Cheoah River, Graham County, N. C.	180	2.78	500	6,700	75	150	2,840
Hiwassee River, Cherokee County, N. C.	550	2.63	1,450	32,200	380	200	11,080
Nottely River, Union County, Ga.	240	1.70	410	1,000	20	40	1,680
Toccoa River, Fannin County, Ga.	240	2.14	510	4,130	60	100	2,880
Hiwassee River, Hiwassee, Ga.	100	2.63	260	2,240	40	100	1,600
Tennessee River, Rabun, Ga.	50	4.35	220	2,720	20	50	3,800
Hiwassee River, near mouth, Tenn.	2,040	2.12	4,300	77,500	1,130	70	70,000
West Chickamauga Creek, Walker County, Ga.	80	2.00	160	5,260	80	60	6,200
South Chickamauga Creek, Catoosa County, Ga.	110	2.00	220	6,330	100	60	7,400
Sequatchie River, Sequatchie County, Tenn.	330	2.00	660	4,000	60	50	5,500

Table 21 shows the effect of the regulated discharge of the stored water along three sections of the river; the first at Knoxville, the second at Chattanooga, and the third below Riverton. The facts given apply to the three sections of the river along which improvement has been attempted, and, although the total storage indicated in Table 20 is not necessary for purposes of navigation, the effects of that storage in increasing the stage of the river during low-water seasons are given in Table 21:

TABLE 21.—*Tennessee River.*

SECTION AT KNOXVILLE.

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cu. ft. per sec.*	*Days.*	*Days.*	*Days.*
1	970	4,250	3,187	2,125
2	3,220	1,280	960	640
3	6,380	647	485	323
4	9,930	416	312	208
5	13,700	300	225	150
6	17,670	233	174	116
7	21,840	189	142	95
8	26,210	157	117	78
9	30,780	134	100	67
10	35,300	117	87	58

TABLE 21.—*Tennessee River*—Continued.

SECTION AT CHATTANOOGA.

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cu. ft. per sec.*	*Days.*	*Days.*	*Days.*
1	2,780	2,890	2,167	1,445
2	6,540	1,230	922	615
3	11,040	728	546	364
4	16,000	502	376	251
5	25,580	314	235	157
6	27,870	288	216	144
7	34,470	233	174	116
8	41,070	196	147	98
9	47,670	168	126	84
10	54,270	148	111	74

SECTION BELOW RIVERTON.

1	1,440	5,600	4,200	2,800
2	4,200	1,900	1,430	950
3	7,600	1,060	790	530
4	11,500	700	520	350
5	15,900	500	380	250
6	20,800	390	290	195
7	26,000	310	230	155
8	31,600	250	190	125
9	37,500	210	160	105
10	43,600	180	138	90

OHIO RIVER.

This brings the discussion to a point where the consideration of the effects of storage reservoirs upon navigation in the Ohio itself can be taken up. To show fully what the effect would be it would be necessary to have complete figures of storage capacity on all the upland drainage areas contributing to the Ohio. Such complete data are not at hand, and it will be necessary, therefore, to confine statements to the effect of the three streams that have been discussed, namely, the Monongahela, the Kanawha, and the Tennessee. This will by no means do justice to the situation. Whatever is shown to be the effect on the Ohio of discharge from the reservoirs on these upland rivers, it should be remembered that such effect is far less than that which would take place were all contributory basins included in the estimate.

A complete treatment of the subject would involve an investigation of the effect of the reservoirs mentioned on numerous sections of the Ohio, from the mouth of the Monongahela to Cairo, Ill., but in the limited space of this paper it will be possible to consider only three representative sections, at Wheeling, W. Va., Huntington, W. Va., and Paducah, Ky.

The following is a résumé of the attempts that have been made to render the river navigable during low-water seasons in the project under which the Government is now working for the improvement of the Ohio.

Work was commenced by the Federal Government on the Ohio River in 1827; it has embraced the removal of obstructions, the construction, repair, and maintenance of low concentrating dikes and dams, bank protection, and the building and repair of levees. The Government had expended up to June 30, 1905, the sum of $6,696,000. Commerce on the river during the calendar year 1905, so far as reported, was approximately 13,000,000 tons, valued at $22,000,000, together with more than 4,000,000 passengers.

Permanent improvements so far made on the Ohio River consist of the construction of several locks and dams, which are intended to be the first of a series which will constitute a general system of canalization. In the river and harbor act approved March 3, 1905, is a provision for the appointment of a board of engineers "to examine the Ohio River and report at the earliest date by which a thorough examination can be made, the necessary data with reference to the canalization of the river, and the approximate location and number of locks and dams in such river, with a view both to a depth of 6 and 9 feet; and to include the probable cost of such improvement with each of the depths named, the probable cost of maintenance and the present prospective commerce on said river," etc. The report of this board of engineers had not been made at the time of the issuance of the last annual report of the Chief of Engineers, but the intent of the act is plain, viz, to determine upon a scheme of canalization in pursuance of the plan already started. A great many locks and dams will be needed to complete the canalization of the river, for the Ohio at times flows so low that navigation throughout the greater part of the stretch is entirely suspended. In view of the approach of this report it is extremely pertinent to consider what may be done by the use of conservation reservoirs.

For the three sections mentioned rating tables have been made showing the effect of increased discharge on the height of the river at these sections. The Ohio section at Wheeling shows the effect of the discharge of stored water on the Monongahela River alone, that at Huntington the combined effect of the Monongahela and Kanawha, while that at Paducah presents the effect of the Monongahela, Kanawha, and Tennessee. Table 22 embodies this information.

TABLE 22.—*Ohio River.*

SECTION AT WHEELING.

Increase of stage.	Flow required.	Duration of flow.		
		Reservoirs full.	Reservoirs three-fourths full.	Reservoirs one-half full.
Feet.	*Cu. ft. per sec.*	*Days.*	*Days.*	*Days.*
1	3,000	540	405	270
2	6,700	240	180	120
3	11,610	139	105	70
4	18,020	90	67	45
5	25,300	64	48	32
6	32,800	49	37	25

SECTION AT HUNTINGTON.

1	8,100	580	430	290
2	17,600	267	200	133
3	28,600	164	123	82
4	39,600	118	89	59
5	51,600	91	68	46
6	63,600	74	55	37
7	77,600	60	45	30

SECTION AT PADUCAH.

1	11,000	1,160	870	580
2	24,000	530	400	265
3	39,000	330	245	165
4	55,000	232	174	116
5	68,000	187	140	94
6	83,000	153	115	76
7	98,000	94	71	47

Table 22 shows that available storage facilities in the Monongahela basin alone will serve to increase the stage at Wheeling 3 feet for considerably more than four months, while the combined effect of the Monongahela and Kanawha at Huntington will afford an increase of 4 feet above the low stage for four months. In the third part of the table the effect of stored water from the Tennessee is appreciable, and it is seen that for a period of one hundred and fifty-three days, or five months, an additional stage of 6 feet could be maintained in this section.

CONCLUSION.

In conclusion, the figures given in this report bear out the statement made at the beginning that the proper improvement of many rivers may be practically and thoroughly accomplished only by the use of storage reservoirs and the retention of the forest cover. On some of the rivers the possibilities are greater than on others and on some, like the Yadkin, the possibility of maintaining high navigable stages during low-water seasons is considerably greater than

is shown in the table. No rated section was available in the lower or navigable portion of the Yadkin and it was necessary to make the estimate on a section of high slope in which the increase of stage due to increment of stored water is not as great as it would be below. Moreover, on several of the streams, because of lack of survey, only a part of the upland drainage areas was considered and the results given are based only on the storage discovered along the surveyed portions. The effects are in no case overestimated; on the other hand, with many of the rivers the possibilities are far greater than are shown in the tables.

The second important point brought out in this report is that conservation of stream flow depends upon the condition of the drainage area, and that to insure the perpetuation of the proper conditions it is necessary to preserve the forests and keep the land surfaces intact. If this is done by such reservation, many values will be affected. The conservation of flood waters and the increase of water power are among the most important, but in the consideration of the cost of this reserve it should be borne in mind that, disregarding all other improvements, the benefit accruing to navigation alone would more than justify the necessary expenditure. Therefore, the preservation of timber resources, of water power, the prevention of flood damages, may, if need be, be considered as collateral benefits, though these benefits equal in importance the benefit to navigation.

Approved:

JAMES WILSON,
Secretary of Agriculture.

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